SITE SELECTION FOR THE FIRST SUSTAINABLE MARS BASE

Workshop Abstract #2001

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NASA/TM-98-206538

Resource Utilization and Site Selection for a Self-Sufficient Martian Outpost

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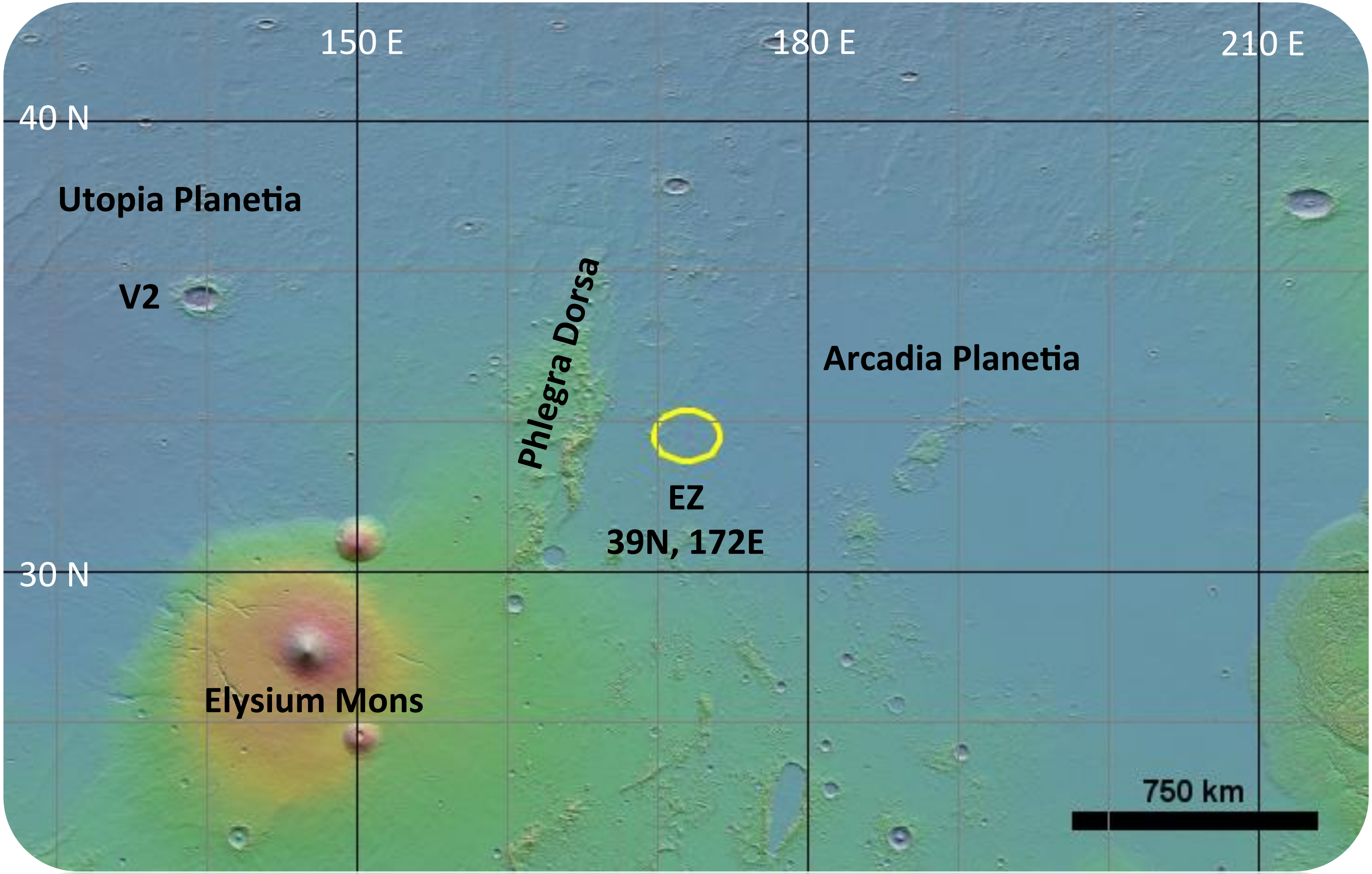
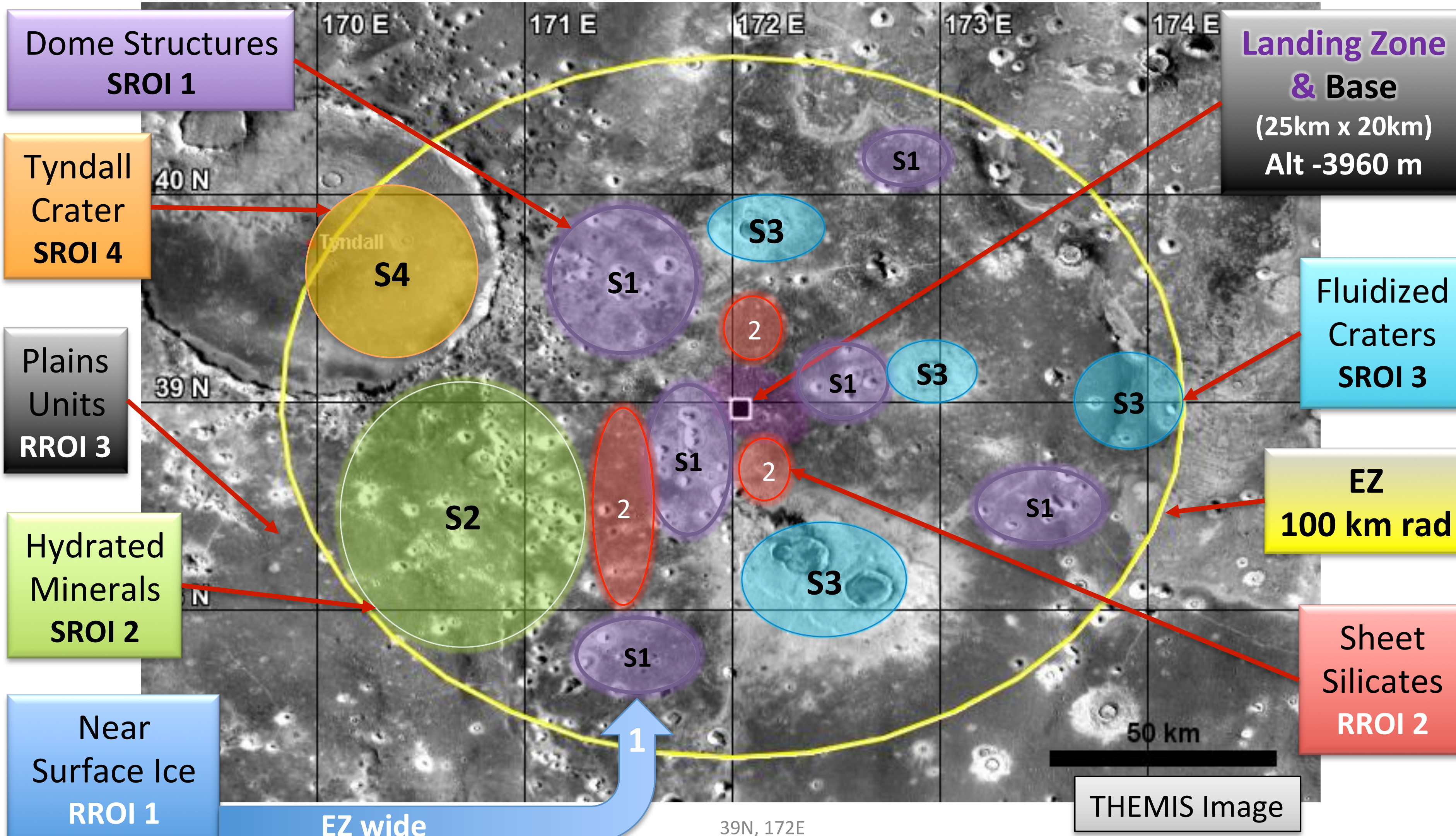
April 1998

Exploration Zone Map #1002



Exploration Zone Map #1002

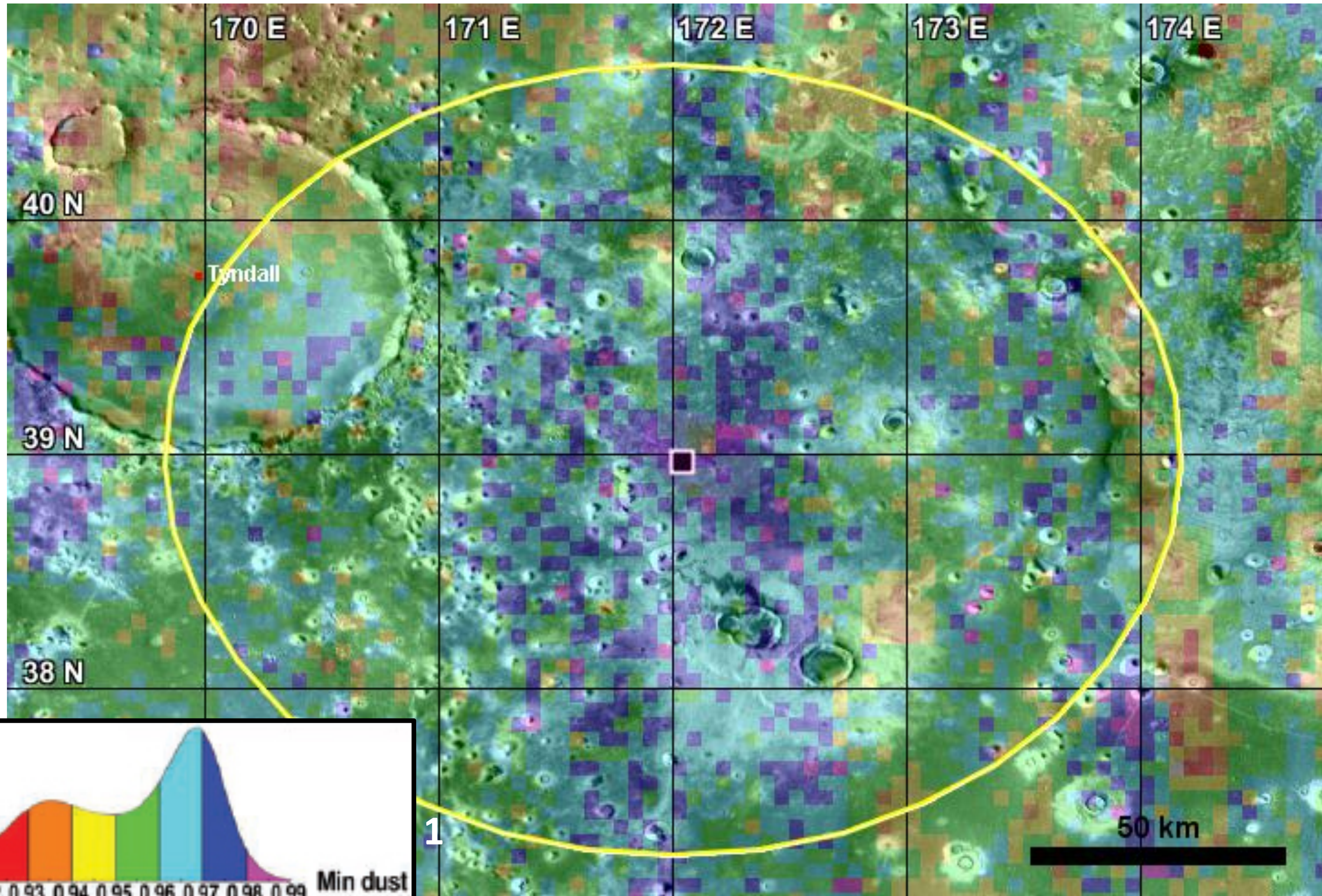
All RROIs are SROIs but all SROIs are not necessarily RROIs !



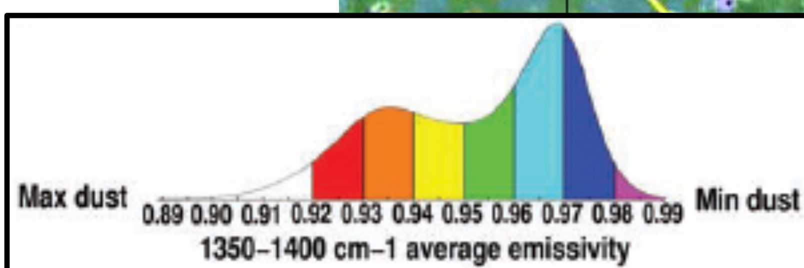
39N, 172E

Exploration Zone Map #1002

TES Dust Cover Index (DCI)



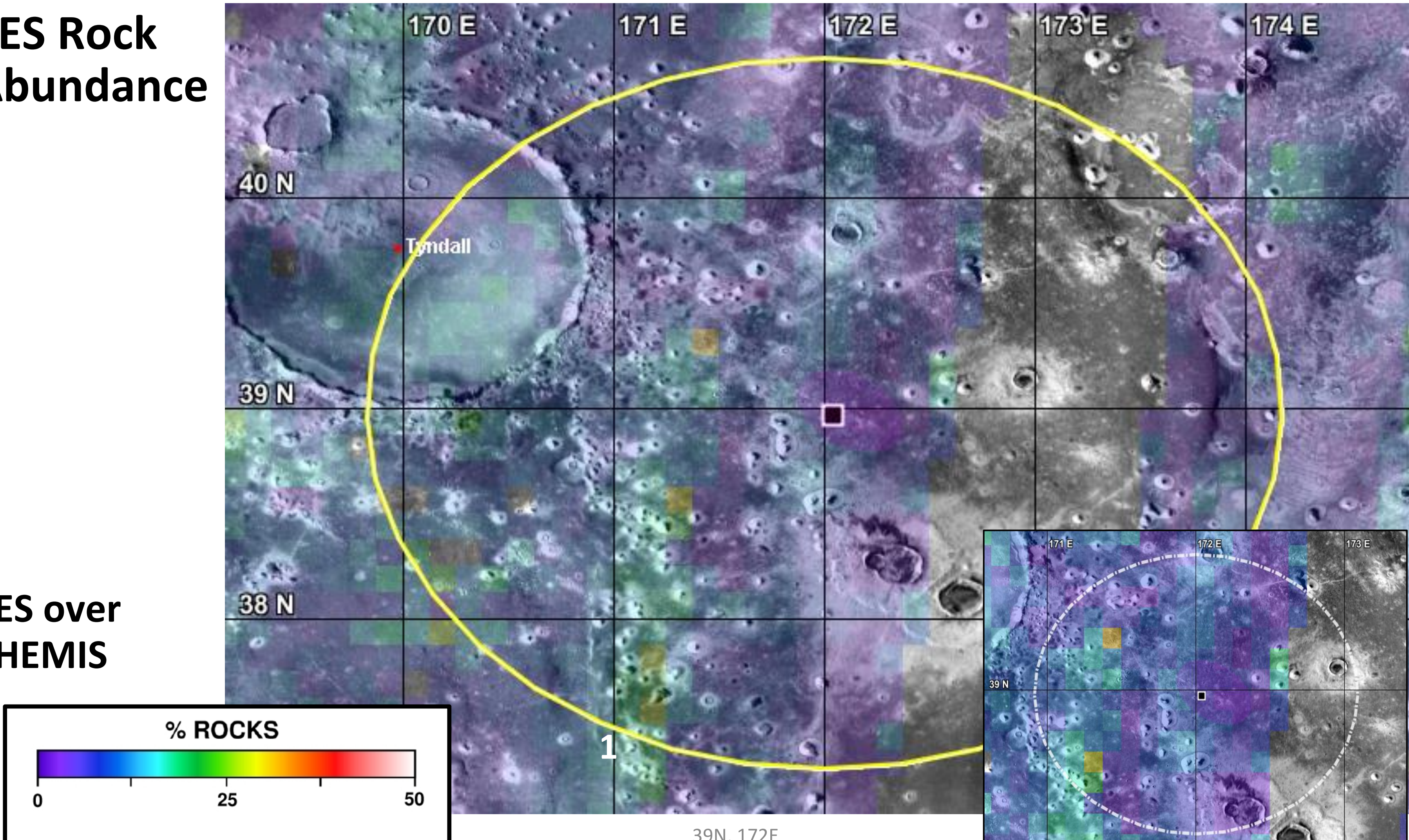
TES over THEMIS



Exploration Zone Map #1002

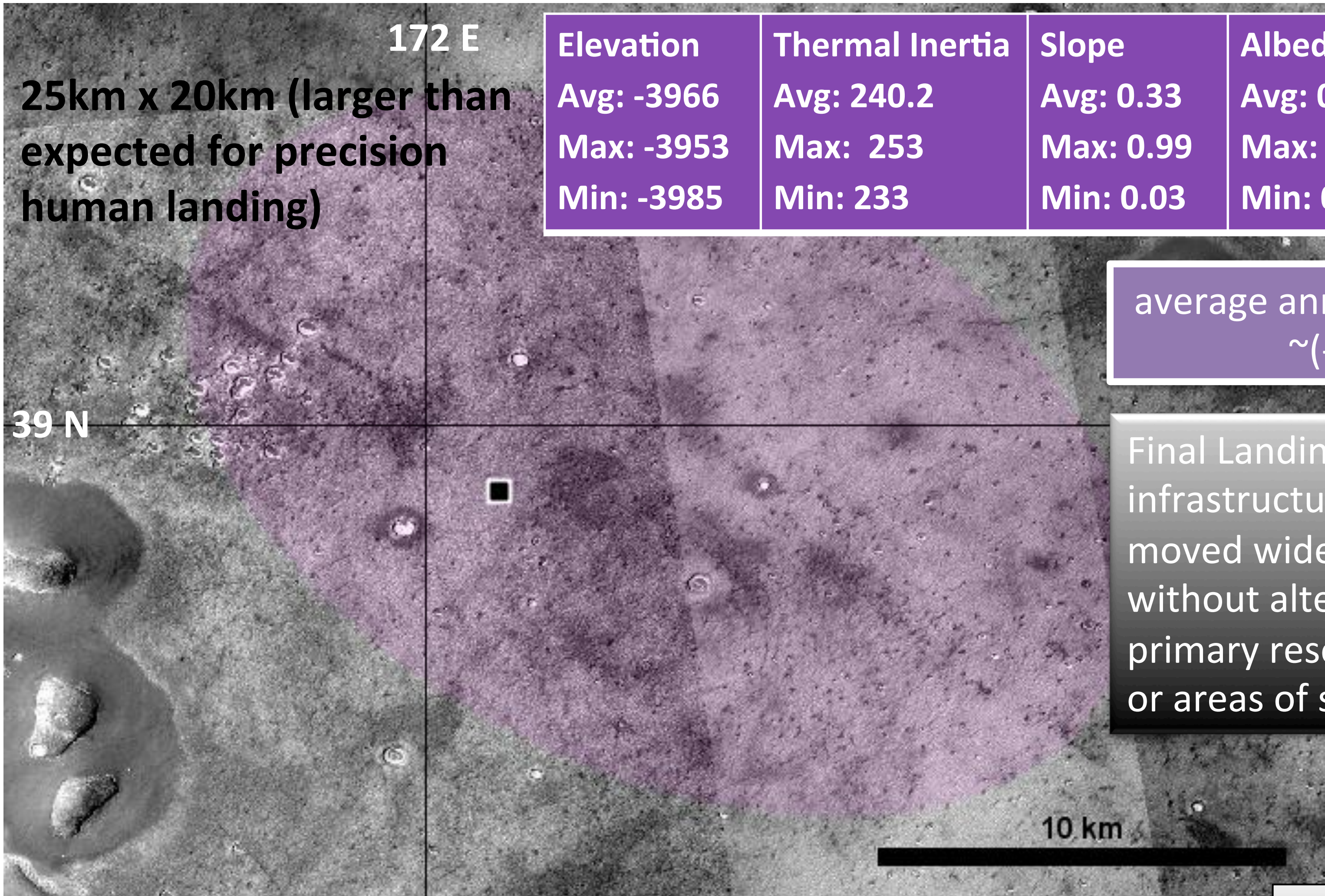
TES Rock Abundance

TES over THEMIS



39N, 172E

Landing Zone



Elevation	Thermal Inertia	Slope	Albedo	Dust Index
Avg: -3966	Avg: 240.2	Avg: 0.33	Avg: 0.156	Avg: 0.968
Max: -3953	Max: 253	Max: 0.99	Max: 0.996	Max: 0.983
Min: -3985	Min: 233	Min: 0.03	Min: 0.025	Min: 0.949

average annual temperature ~(-73.15 C)

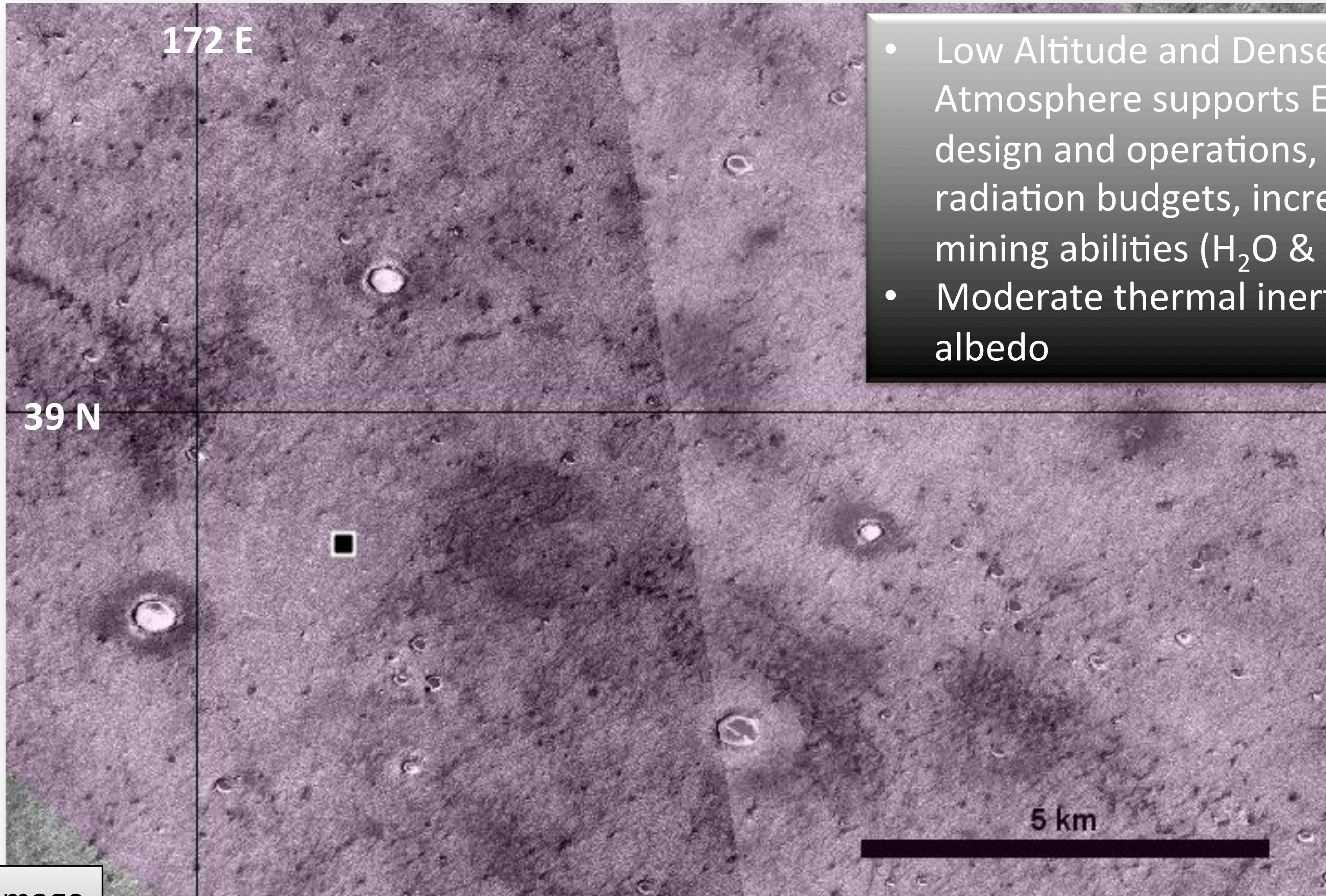
Final Landing Sites and Base infrastructure could be moved widely in this region without altering access to primary resources (i.e., H_2O) or areas of scientific interest.

CTX Image

39N, 172E

Landing Zone

- Low Altitude and Denser Atmosphere supports EDL design and operations, reduced radiation budgets, increases mining abilities (H_2O & CO_2)
- Moderate thermal inertia and albedo



CTX Image

Science ROI(s) Rubric

1st EZ Workshop for Human Missions to Mars

Site Factors					SROI1	SROI2	SROI3	SROI4	RROI1	RROI2	RROI3		EZ SUM
Science Site Criteria	Astrobio	Threshold	AND/OR	**Potential for past habitability**	?	?	?	?	●	?	?		
				Potential for present habitability/refugia	?	?	?	?	○	?	?		
		Qualifying		Potential for organic matter, w/ surface exposure	?	?	?	?	?	?	?		
	Atmospheric Science	Threshold		**Noachian/Hesperian rocks w/ trapped atmospheric gases**	●	?		○	○	?	○		1,3
		Qualifying		Meteorological diversity in space and time	●	●	●	●	●		●		6,0
				High likelihood of surface-atmosphere exchange	●	●	●	○	●				4,2
				Amazonian subsurface or high-latitude ice or sediment	●	●	●	●	●	●	●		6,0
				High likelihood of active trace gas sources	?	?	?	?	○	?	?		0,1
	Geoscience	Threshold		**Range of martian geologic time; datable surfaces**	●	○	●	○	○	○	●		3,4
				Evidence of aqueous processes	●	●	●	●	●	○	●		6,1
				Potential for interpreting relative ages	●	●	●	●	○	○	○		4,3
		Qualifying		Igneous Rocks tied to 1+ provinces or different times	●								1,0
				Near-surface ice, glacial or permafrost	●	●	●	●	●	○	●		5,1
				Noachian or pre-Noachian bedrock units	●		?	○					0,1
				Outcrops with remnant magnetization	●		?						1,2
				Primary, secondary, and basin-forming impact deposits	?	?	●	●					2,0
				Structural features with regional or global context	●	○	●	○	●		●		4,2
				Diversity of aeolian sediments and/or landforms	●	●	●	●	●	●	●		6,0

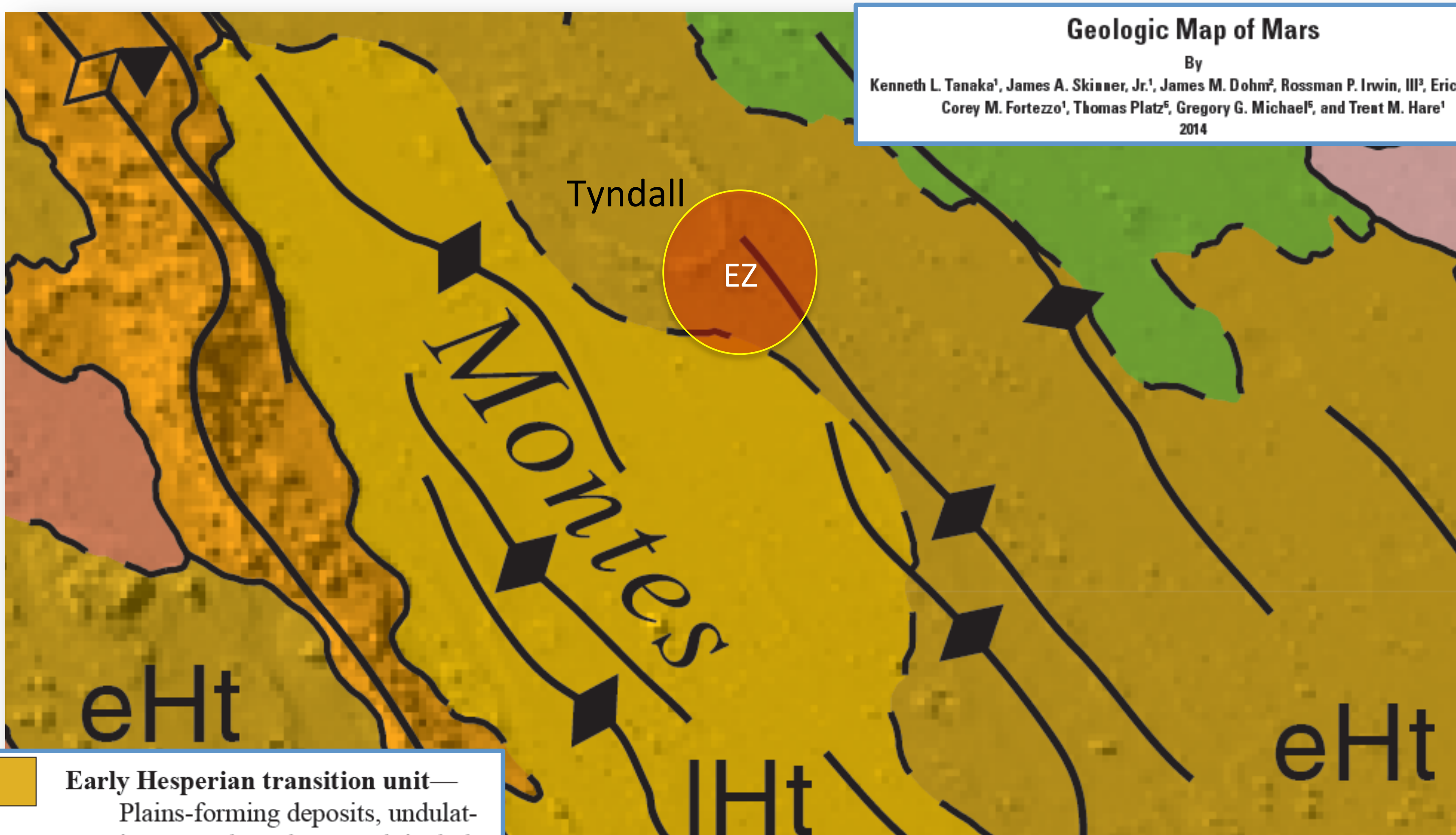
Key	
●	Yes
○	Partial Support or Debated
	No
?	Indeterminate

Resource ROI(s) Rubric

Criteria	Category	Level	Site Factors	SROI1	SROI2	SROI3	SROI4	RROI1	RROI2	RROI3		EZ SUM
ISRU and Civil Engineering Criteria	Engineering		Meets First Order Criteria (Latitude, Elevation, Thermal Inertia)	●	●	●	●	●	●	●		6,0
	Water Resource	Threshold	AND/OR: **Potential for ice or ice/regolith mix**	●	●	●	●	●	●	●		6,0
			AND/OR: **Potential for hydrated minerals**	●	●	●	●	●	●	●		6,0
			Quantity for substantial production	●	●	○	○	●	●	●		2
			Potential to be minable by highly automated systems	●	●			●	●	●		5,0
			Located less than 3 km from processing equipment site	●	●			●	●	●		5,0
			Located no more than 3 meters below the surface	●	●	●	●	●	●	●		7,0
			Accessible by automated systems	●	●	●	●	●	●	●		7,0
		Qualifying	Potential for multiple sources of ice, ice/regolith mix **and** hydrated minerals	●	●	●	●	●		●		5,0
			Distance to resource location can be >5 km	●	●	●	●	●	●	●		7,0
			Route to resource location must be (plausibly) traversable	●	●	●	●	●	●	●		7,0
	Civil Engineering	Threshold	**~50 sq km region of flat and stable terrain with sparse rock distribution**	●	●			●	●	●		5,0
			1–10 km length scale: <10°		●	●	●	●	●	●		6,0
			Located within 5 km of landing site location	●				●	●	●		4,0
		Qualifying	Located in the northern hemisphere	●	●	●	●	●	●	●		7,0
			Evidence of abundant cobble sized or smaller rocks and bulk, loose regolith	●	●	●	●	●	●	●		7,0
			Utilitarian terrain features	●	●	●	●	●	●	●		7,0
	Food Production	Qualifying	Low latitude	●	●	●	●	●	●	●		7,0
			No local terrain feature(s) that could shadow light collection facilities	●	●	●	●	●	●	●		7,0
			Access to water	●	●	●	●	●	●	●		7,0
			Access to dark, minimally altered basaltic sands	●	●	●	●	●	●	●		7,0
	Metal/Silicon Resource	Threshold	**Potential for metal/silicon**	●	●	●	●	●	●	●		7,0
			Potential to be minable by highly automated systems	●	●	●	●	●	●	●		7,0
			Located less than 3 km from processing equipment site	●	●			●	●	●		5,0
			Located no more than 3 meters below the surface	●	●	●	●	●	●	●		6,0
			Accessible by automated systems	●	●	●	●	●	●	●		7,0
		Qualifying	Potential for multiple sources of metals/silicon	●	●			●	●	●		5,0
			Distance to resource location can be >5 km			●	●					2,0
			Route to resource location must be (plausibly) traversable	●	●	●	●	●	●	●		5,0

Key	
●	**Yes**
○	**Partial Support or Debated**
	No
?	**Indeterminate**

EZ Geological Context



Geologic Map of Mars

By

Kenneth L. Tanaka[1], James A. Skinner, Jr.[1], James M. Dohm[2], Rossman P. Irwin, III[3], Eric J. Kolb[4], Corey M. Fortezzo[1], Thomas Platz[5], Gregory G. Michael[5], and Trent M. Hare[1]

2014

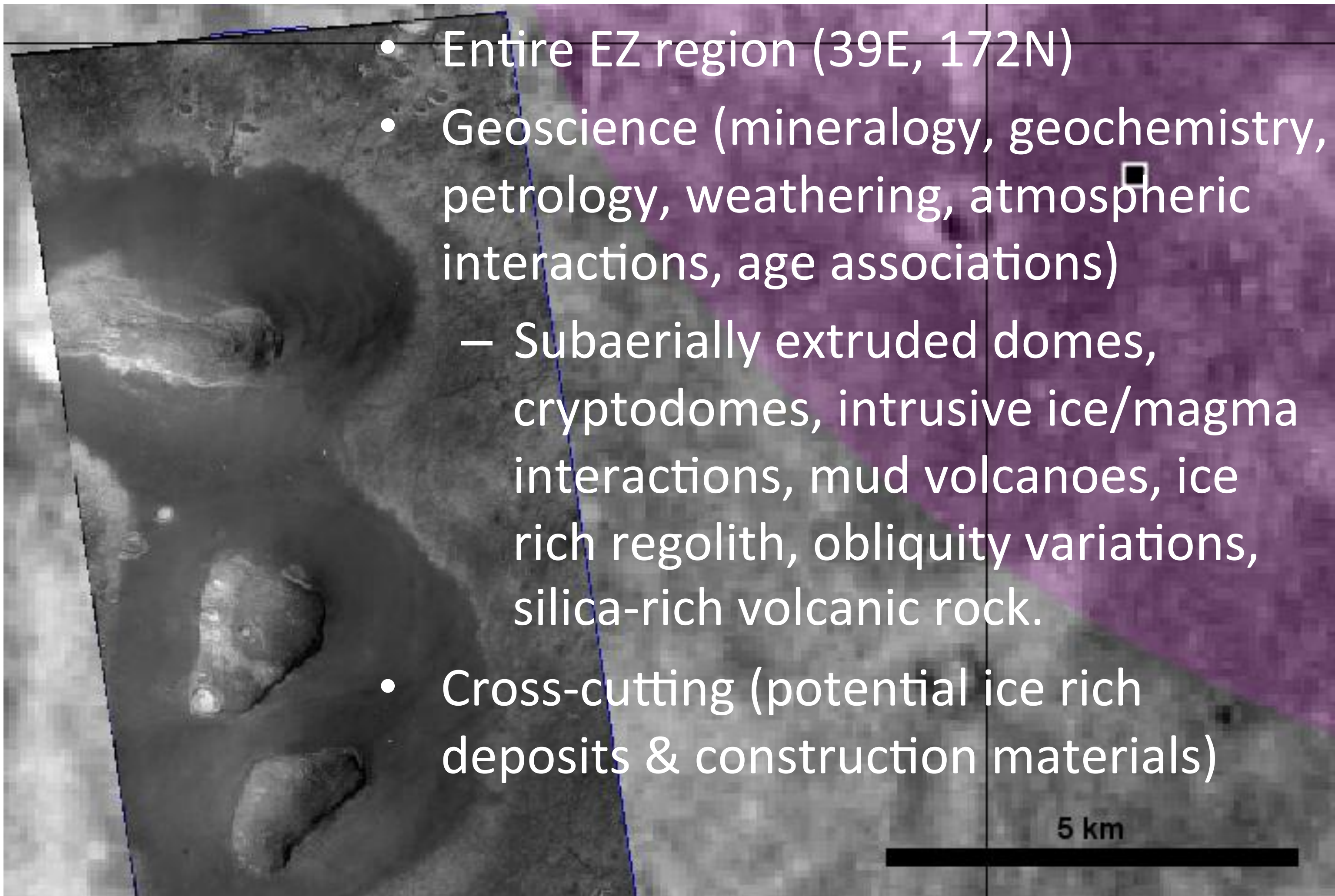
eHt **Early Hesperian transition unit**—Plains-forming deposits, undulating to moderately rugged; includes scattered low knobs and mesas of Noachian highland material.

39N, 172E

Science ROI 1

The more you look, the more you question, the less you know!

Tyndall Dome Field (TDF)



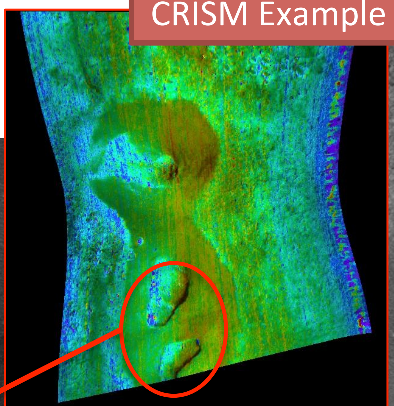
- Entire EZ region (39E, 172N)
- Geoscience (mineralogy, geochemistry, petrology, weathering, atmospheric interactions, age associations)
  - Subaerially extruded domes, cryptodomes, intrusive ice/magma interactions, mud volcanoes, ice rich regolith, obliquity variations, silica-rich volcanic rock.
- Cross-cutting (potential ice rich deposits & construction materials)

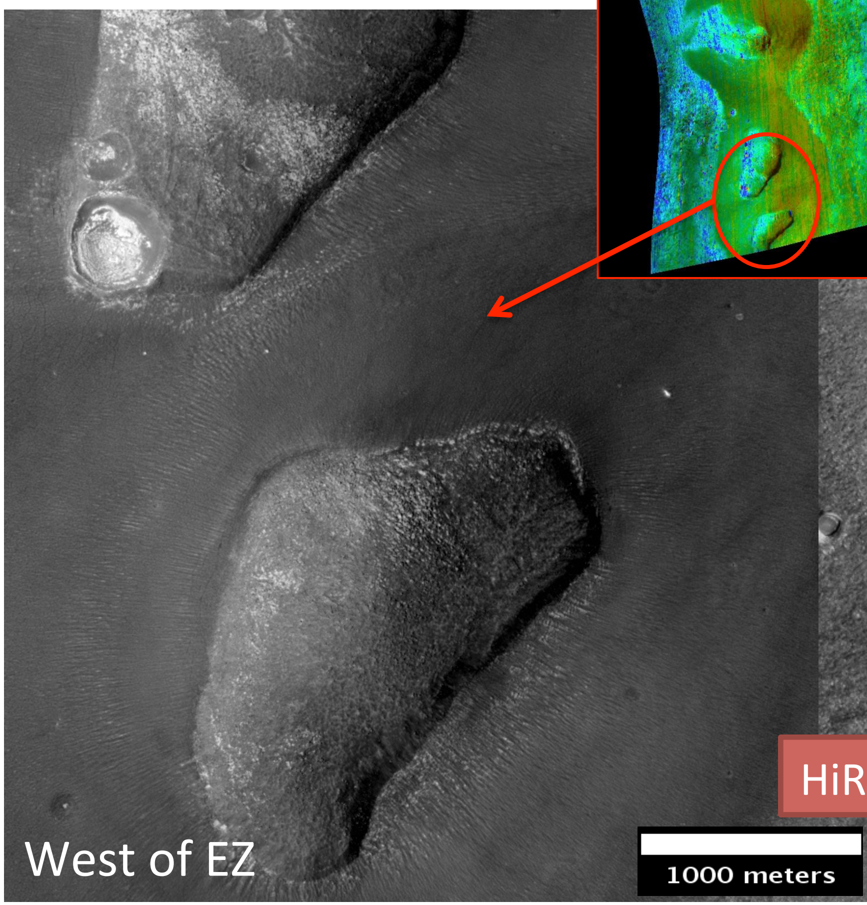
CTX over THEMIS

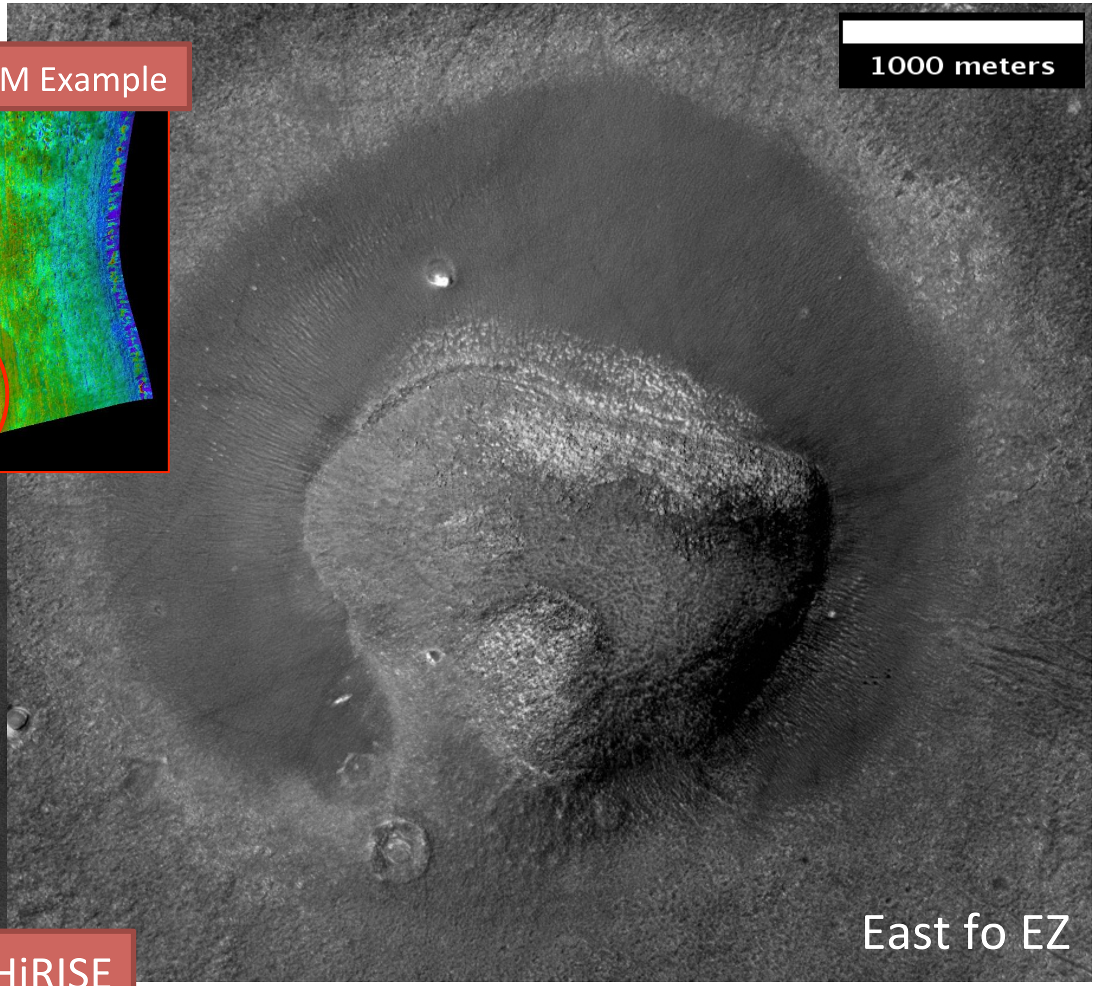
(Rampey et al., 2007; Farrand et al., 2011; Michaut et al., 2013)

Science ROI 1

Tyndall Dome Field (TDF)







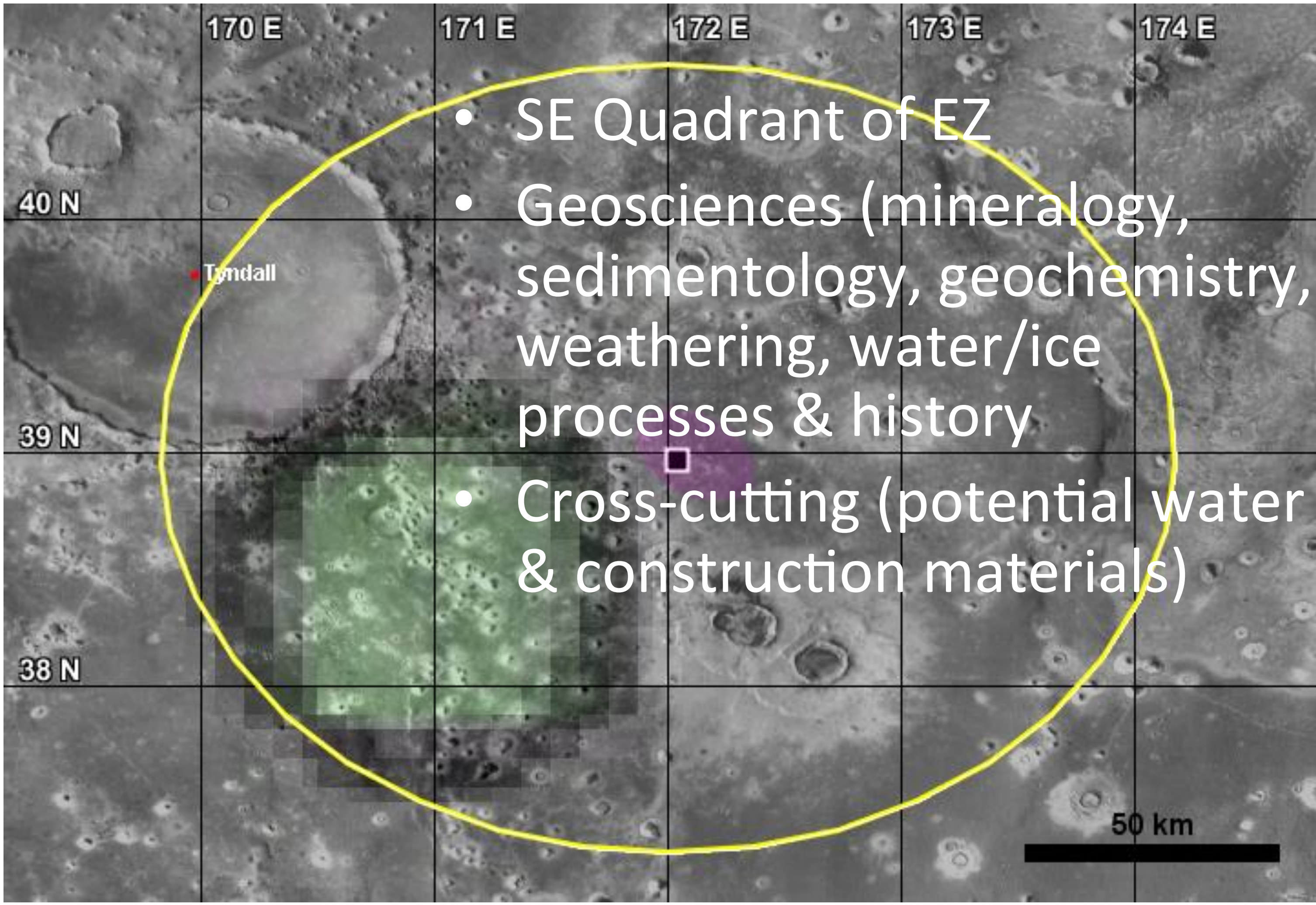
Note: polygonal and “brain terrain”

39N, 172E

Science ROI 2

Hydrated Mineralogy

- SE Quadrant of EZ
- Geosciences (mineralogy, sedimentology, geochemistry, weathering, water/ice processes & history
- Cross-cutting (potential water & construction materials)



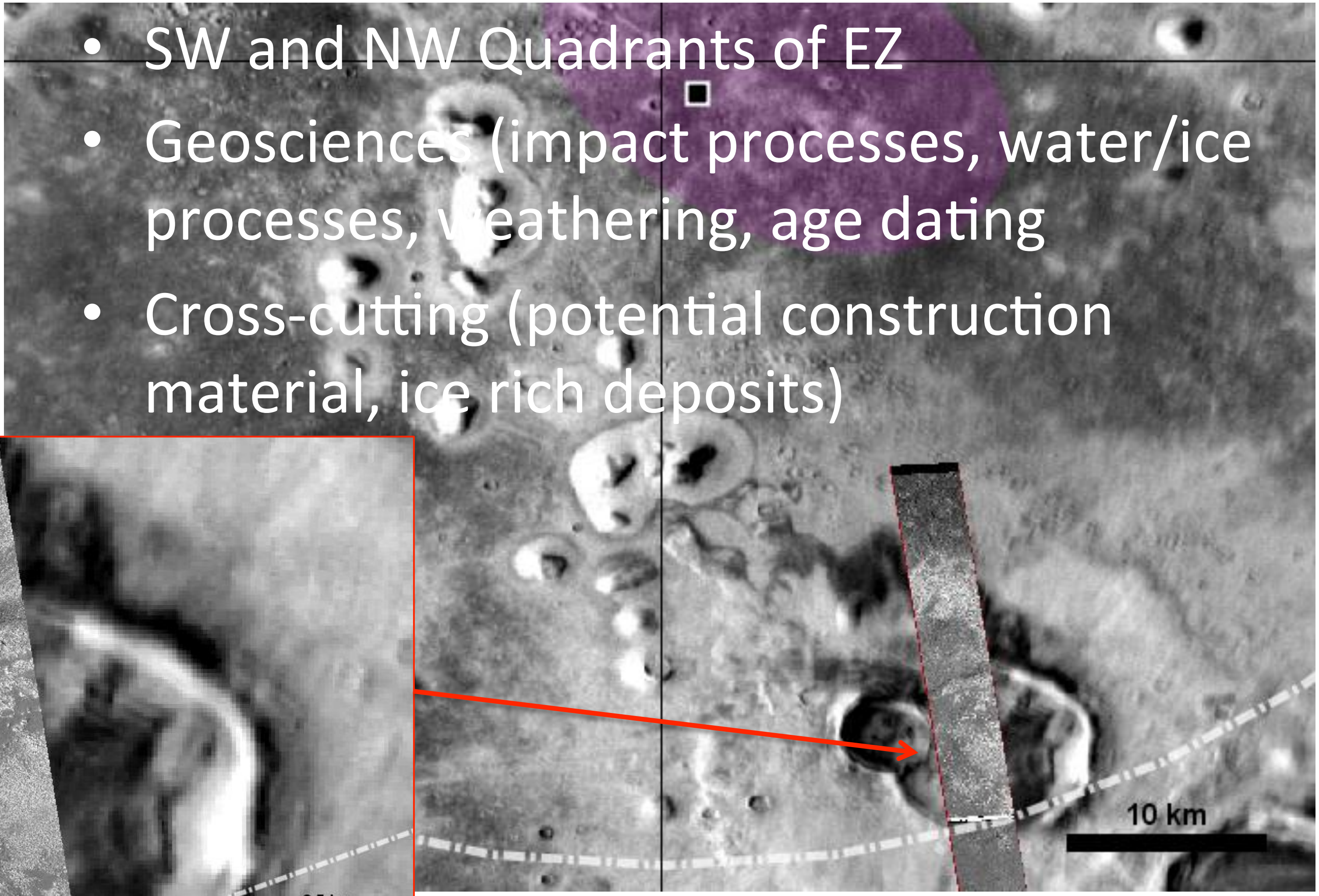
OMEGA over THEMIS

39N, 172Ec

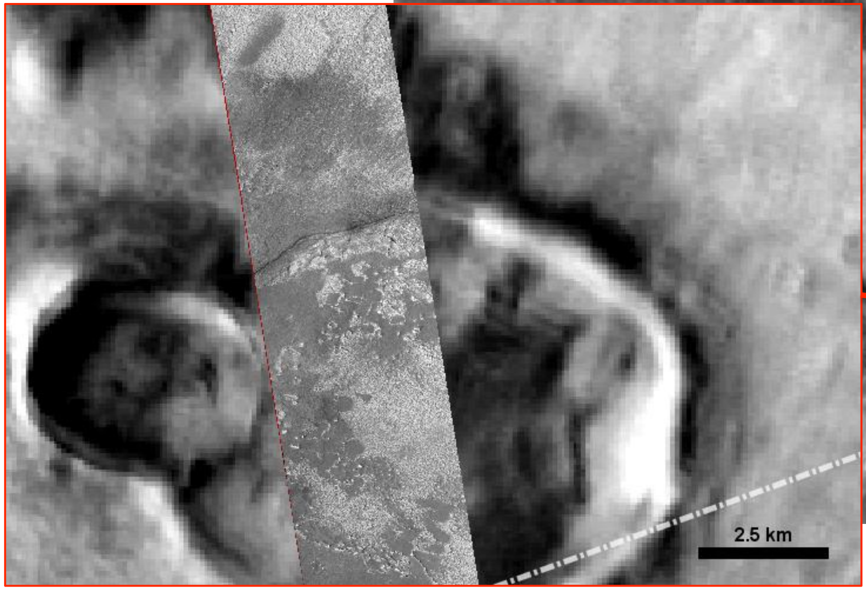
Science ROI 3

Fluidized Impact Structures

- SW and NW Quadrants of EZ
- Geosciences (impact processes, water/ice processes, weathering, age dating
- Cross-cutting (potential construction material, ice rich deposits)



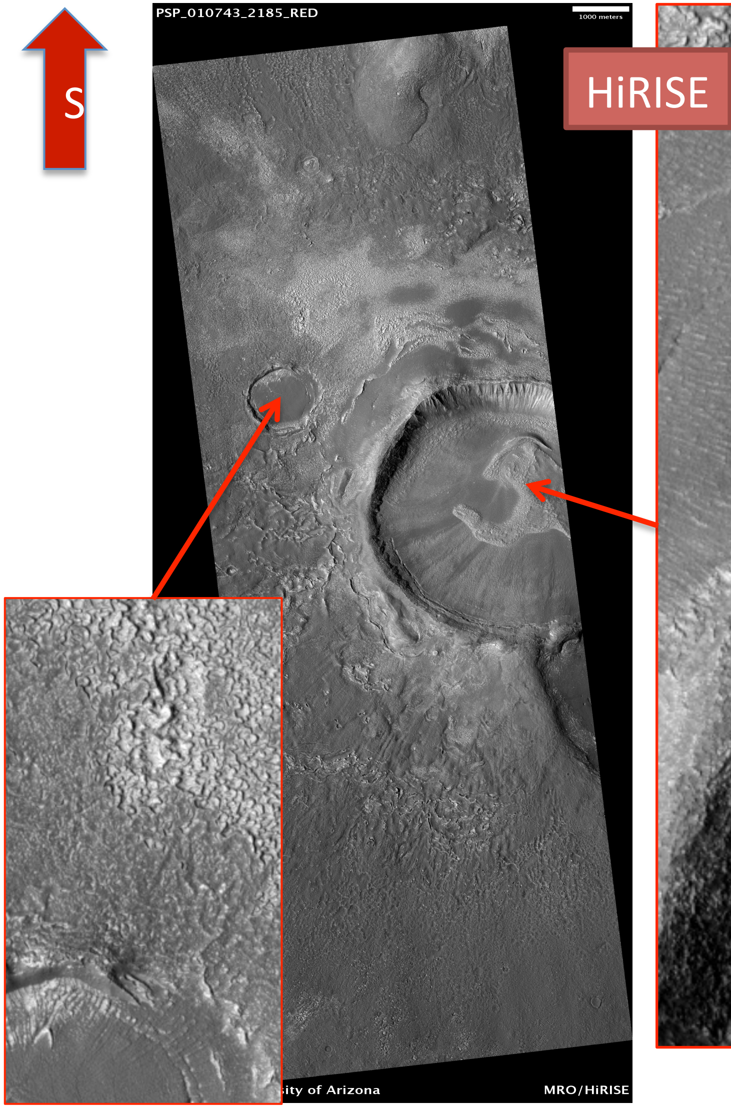
MOC over THEMIS



39N, 172Ec

Science ROI 3

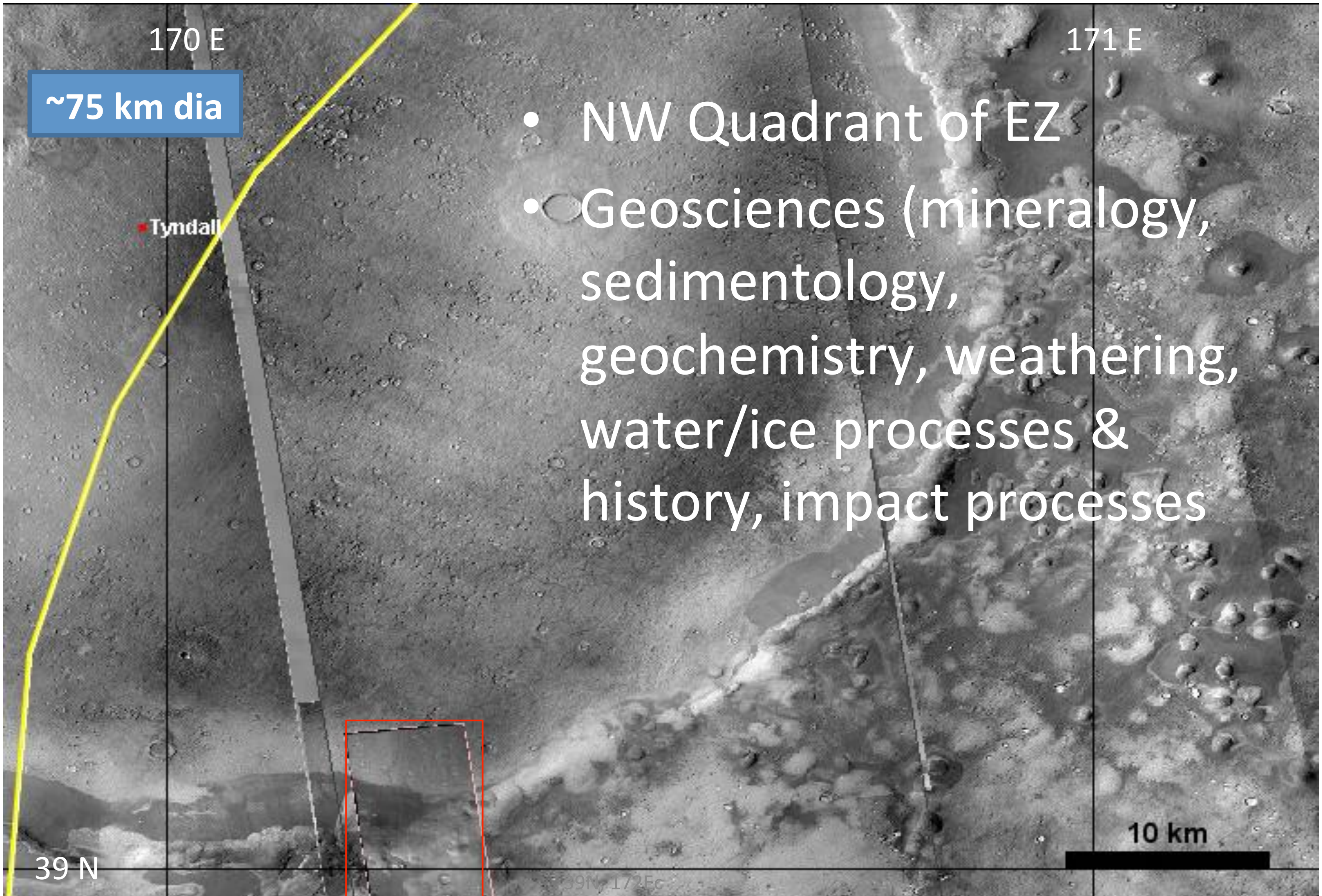
S



39N, 172Ec

Science ROI 4

Tyndal l Crater

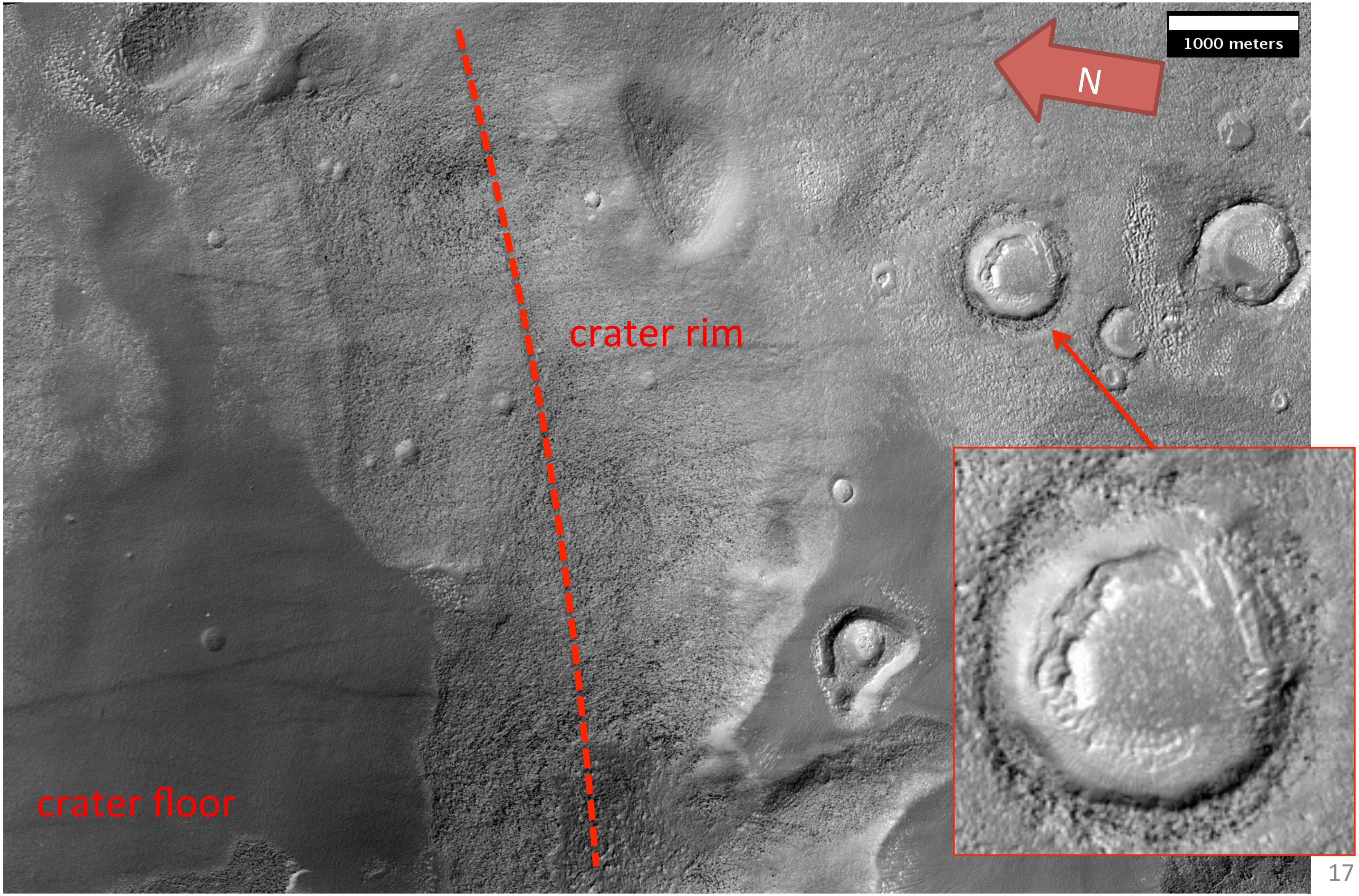


- NW Quadrant of EZ
- Geosciences (mineralogy, sedimentology, geochemistry, weathering, water/ice processes & history, impact processes

CTX & HiRISE

Science ROI 4

Tyndall Crater

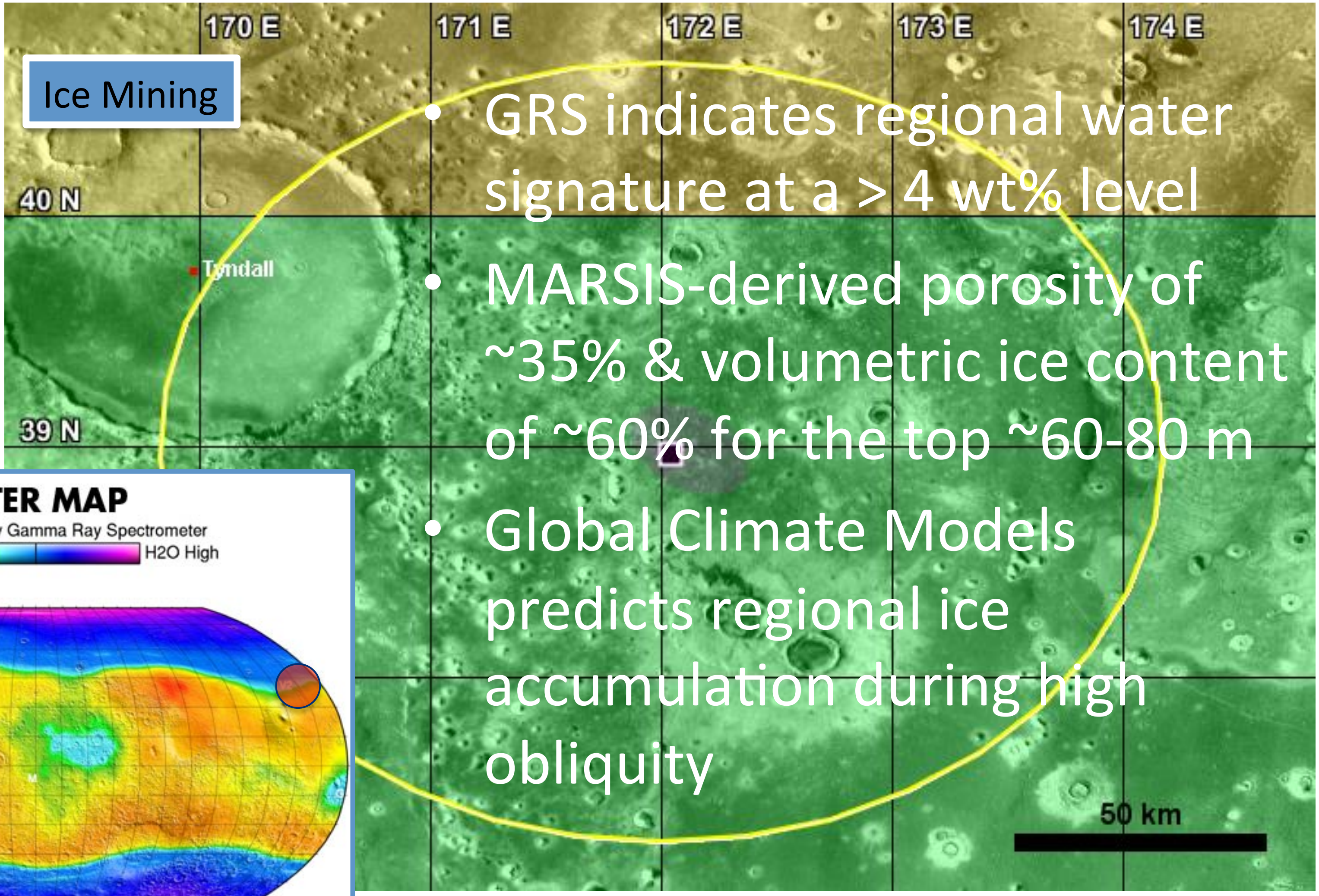


HiRISE

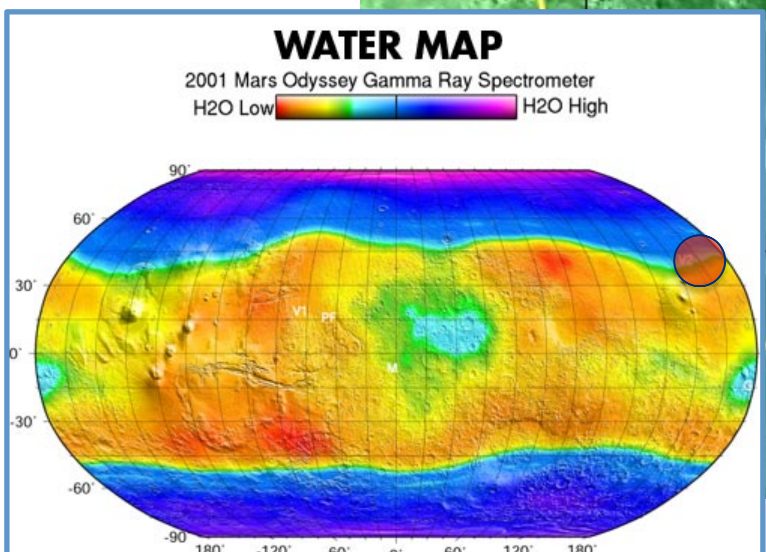
Resource ROI 1

Near Surface Ice

GRS over THEMIS



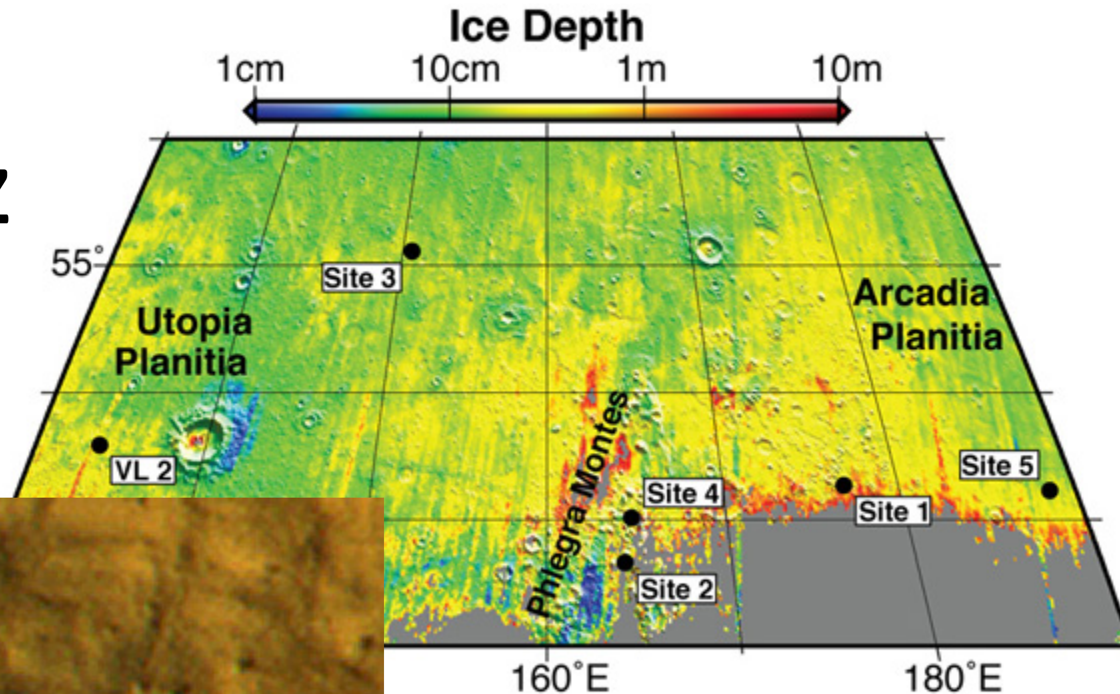
- GRS indicates regional water signature at a > 4 wt% level
- MARSIS-derived porosity of ~35% & volumetric ice content of ~60% for the top ~60-80 m
- Global Climate Models predicts regional ice accumulation during high obliquity



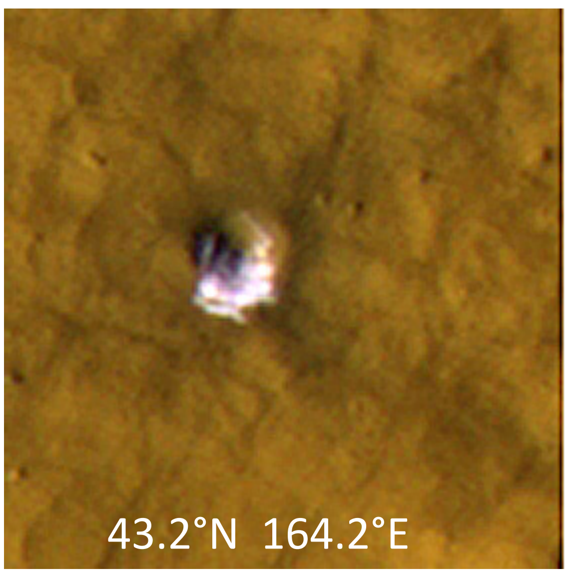
39N, 172Ec

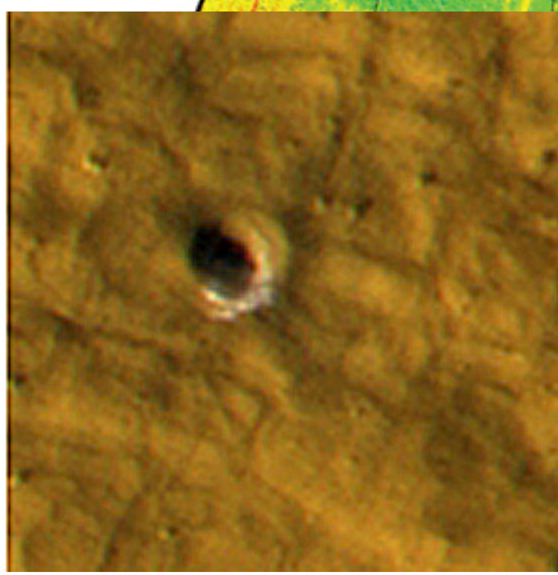
Resource ROI 1

Near Surface Ice Observations SE of EZ



Site 2: HiRISE PSP_010440_2235





6-meter-wide, ~1.33 meter-deep crater Oct. 18, 2008, (left) and on Jan. 14, 2009. Each image is 35 meters across.

39N, 172Ec

A little on Mining/Extraction

Where's the Energy?

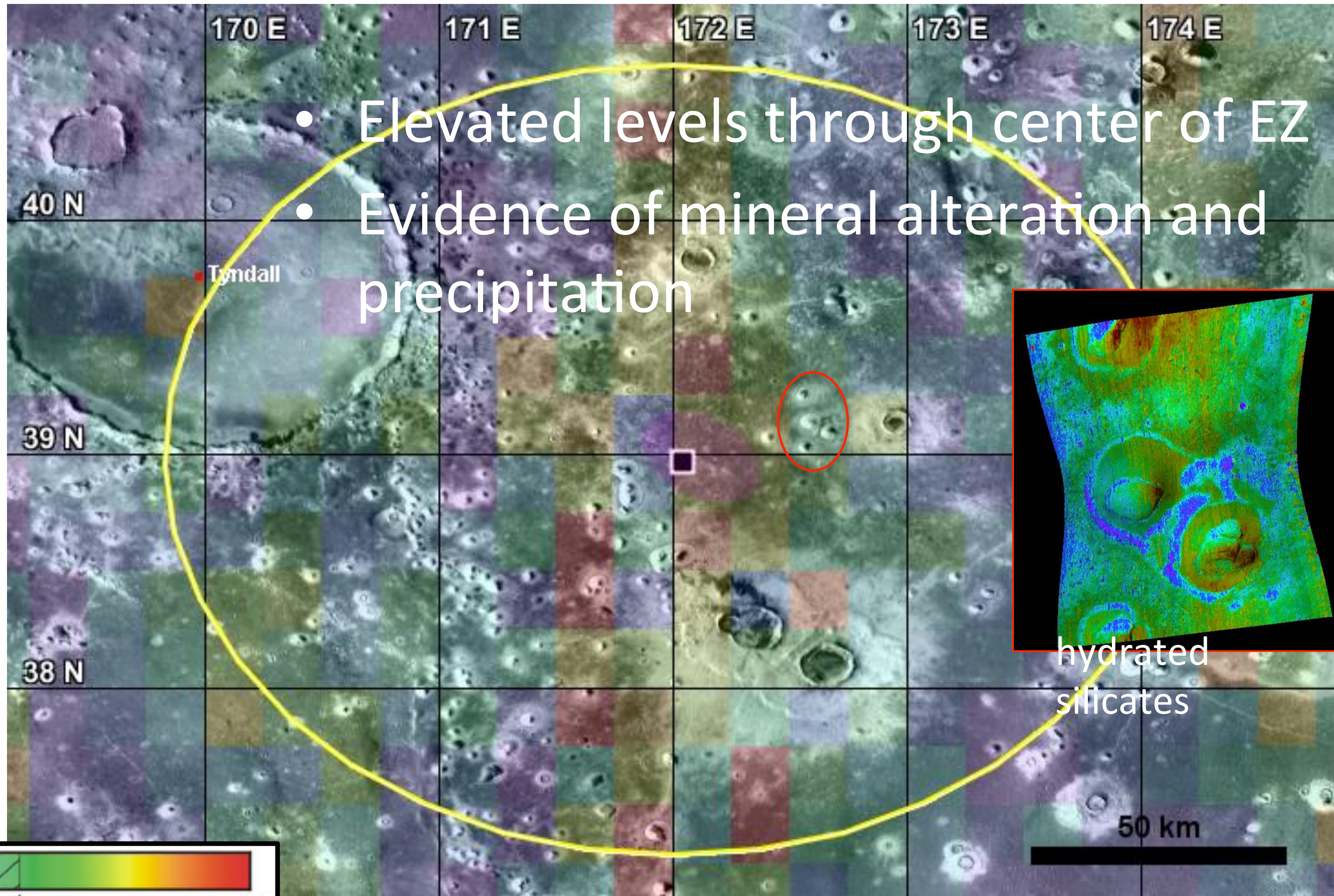
On Earth, **Aluminum** is obtained from the mineral **bauxite** (an aluminum oxide (Al_2O_3)) through the process of **electrolysis**. On Mars we have minerals and non-ore rocks. *We have yet to find an traditional "ore" deposit on Mars.

- The melting point of aluminum oxide, **over 2000ºC** requires *lots of energy to melt* the source material so that **ions (Al^{3+}** and **O^{2-}) are free to move to the electrodes** for the electrolysis to work. On Earth, this process is ~6x more costly than the production Fe (reducing method: ore, *coke* and limestone).
- Other melting points:
  - Iron (sulfide or oxide) ore: 1800 °C
  - Glass: 1400 °C to 1600 °C
  - Mafic minerals (e.g., pyroxene) 1000 to 1200 °C
  - Phyllosilicates: > 1000 °C

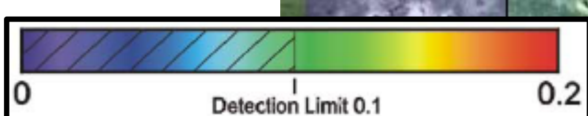
Resource ROI 2

Sheet Silicate / High-Si Glass

- Elevated levels through center of EZ
- Evidence of mineral alteration and precipitation



TES over THEMIS

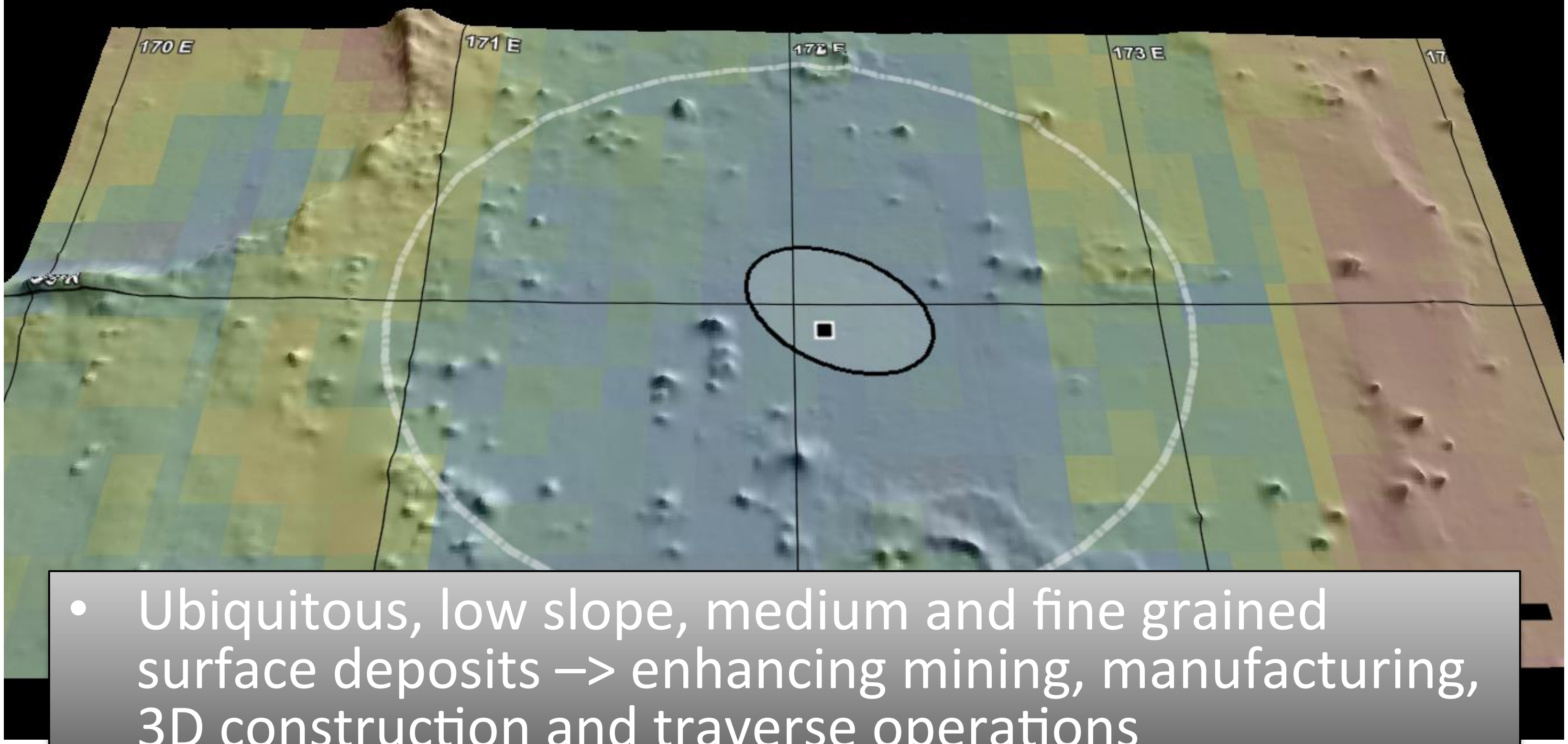


39N, 172Ec

Resource ROI 3

Arcadia Planta Planes Materials

ferric oxide nanoparticles/dust abundance (blue low, red high)



- Ubiquitous, low slope, medium and fine grained surface deposits –> enhancing mining, manufacturing, 3D construction and traverse operations
- Potential for lave tube and tunnels
- Multiple elevated mineral assemblages across region

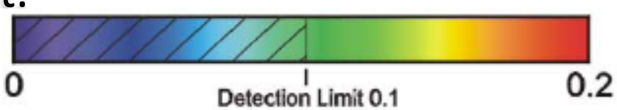
OMEGA over MOLA Shaded Relief

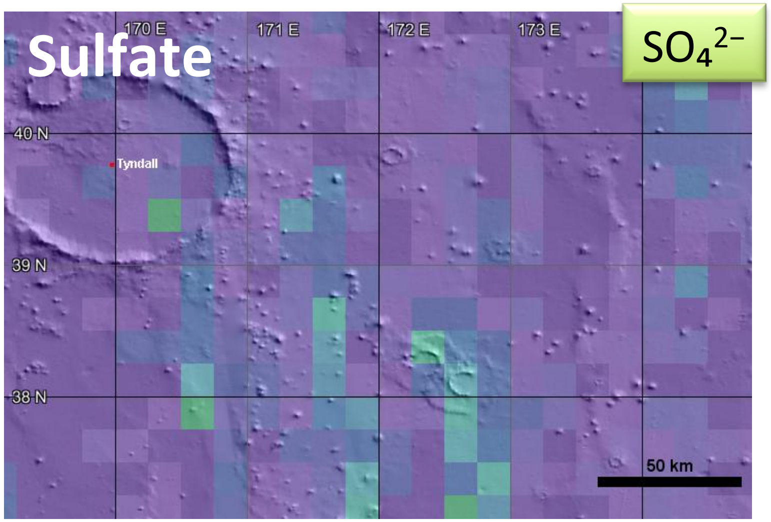
39N, 172Ec

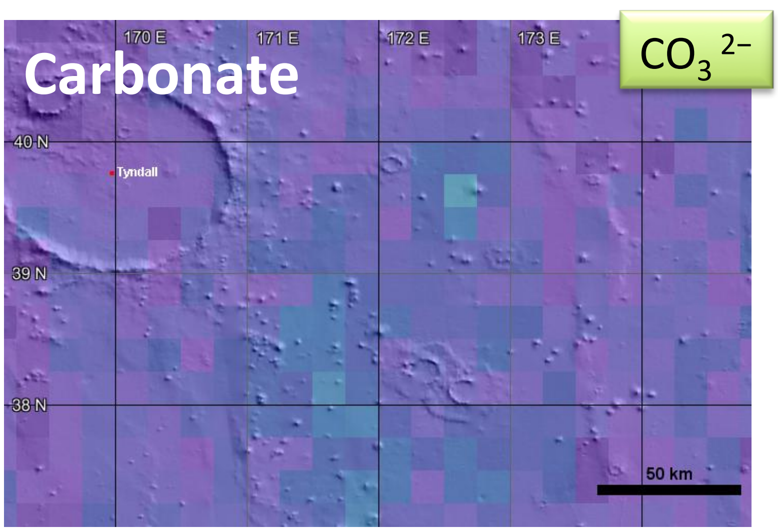
RROI3 Potential Resource ROIs

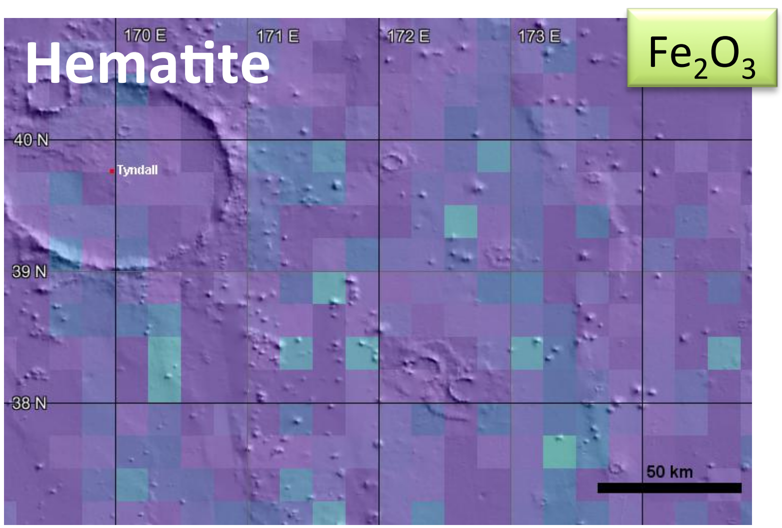
TES Abundances

This EZ contains moderately low to elevated abundances for a variety of minerals and rock types (detection limits need to be enhanced). These provide for a wide range of *potential* resources as well as scientific points of interest.



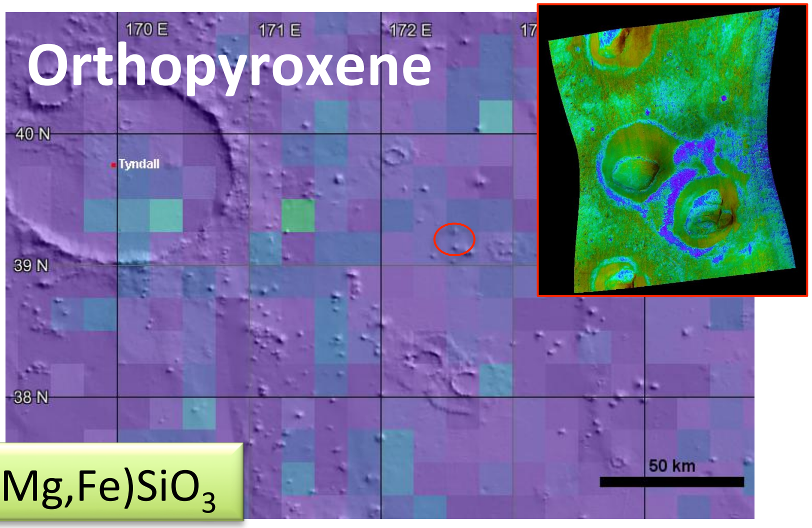




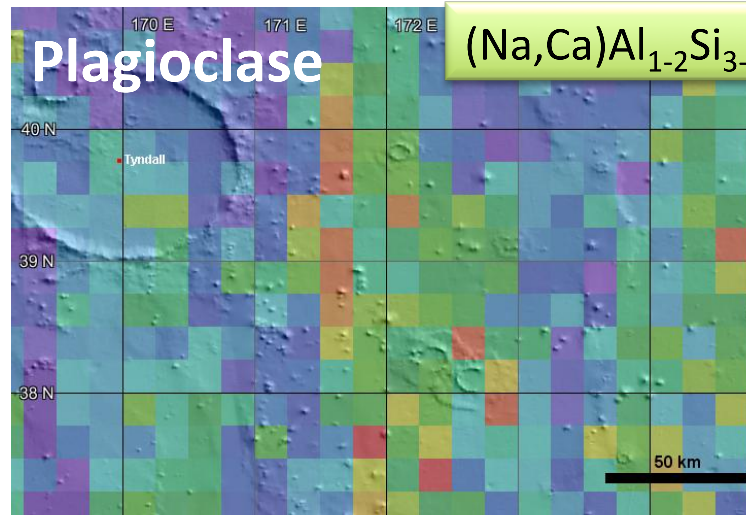


RROI3 Potential Resource ROIs

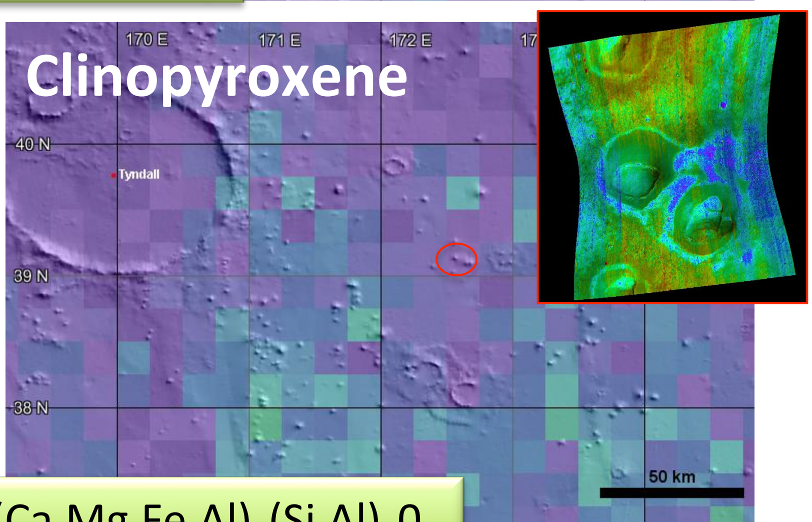
TES Abundances



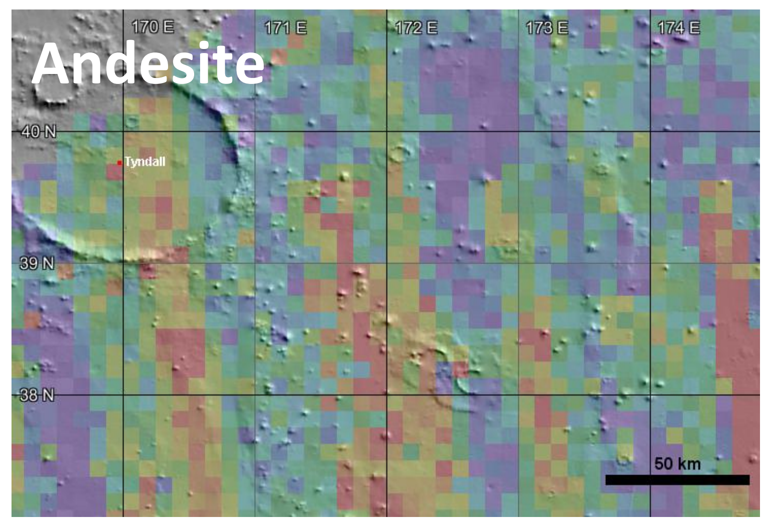
$(Mg,Fe)SiO_3$



$(Na,Ca)Al_{1-2}Si_{3-2}O_8$



$(Ca,Mg,Fe,Al)_2(Si,Al)_2O_6$



39N, 172Ec

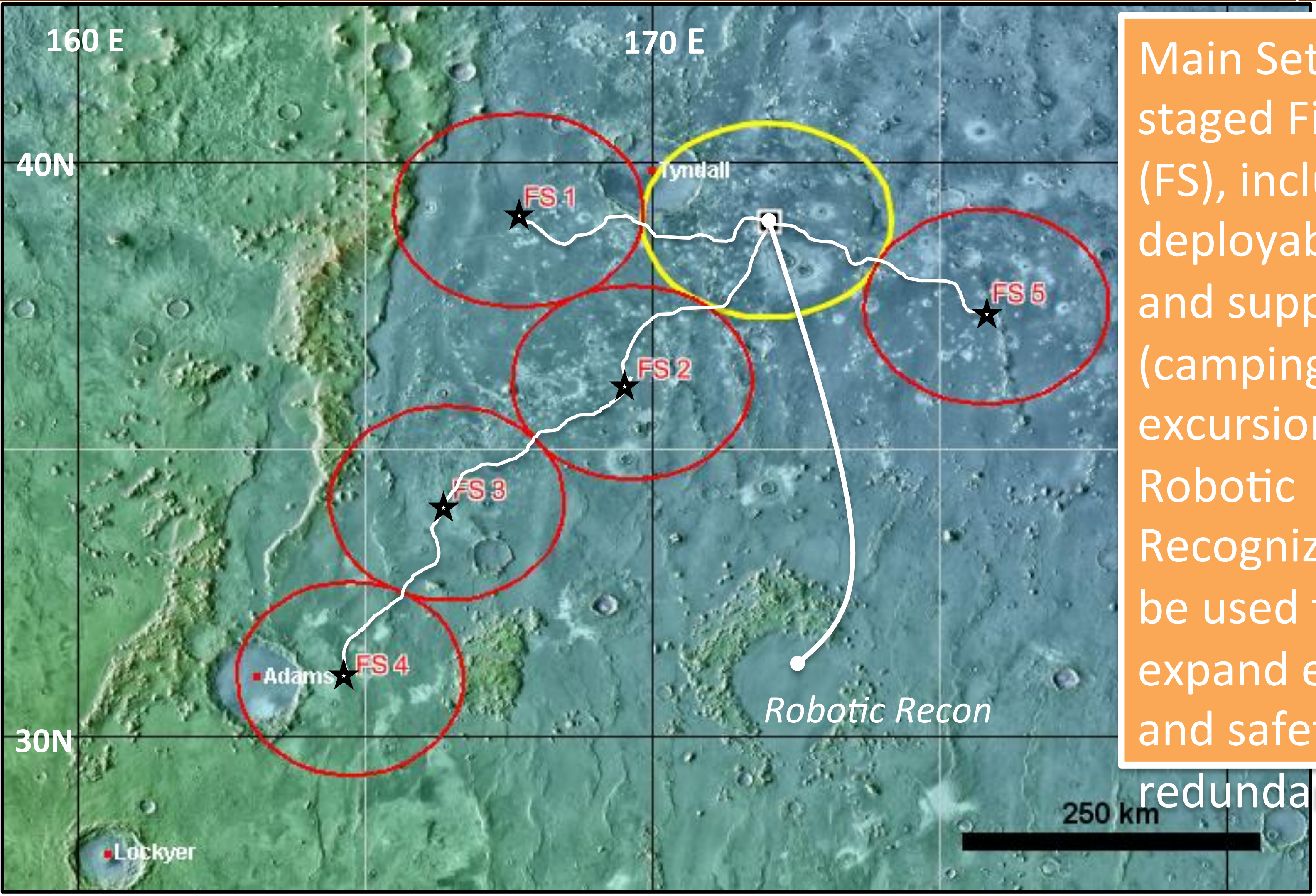
Highest Priority EZ Data Needs

- Locating easily extracted, near surface ice/water deposits is the single most important ongoing data set needed to select a **permanent, growing** and **sustainable** *settlement*. This should include enhanced/high resolution **neutron spectrometer (e.g., GRS)** and **subsurface radar (e.g., SAR, sounding)** at a minimum.
- **CRISM** and **HiRISE** imaging should be enhanced throughout the region.
- Environmental health measures from MARIE or similar instrument should be continued and enhanced

Conclusions

- Our primary driver for landing site selection was driven by the acquisition of water.
- Our assumption being that the primary focus of ***where*** we land and what we do there initially is to mine water, and as such, no traditional science objectives should be delineated in advance of that goal.
- Once suitable sites are found fulfilling proven and producible water needs, than a combined regional assessment of additional resources and science potentials within the EZ can be made as a final form of location optimization.

EZ Concept Corroberation and Possible Evolution

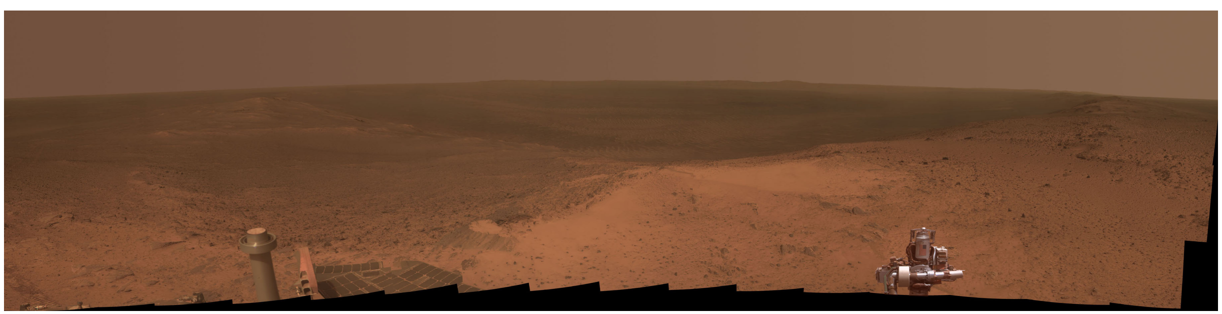


Main Settlement and staged Field Stations (FS), including deployable habitats and supply cashes (camping-excursions) and Robotic Recognizance could be used to vastly expand exploration and safety (network-redundancy)

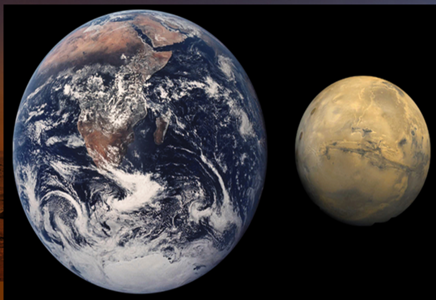
Back Up Slides

A philosophical critique/observation regarding our current path forward, answers to “why” Mars and the reasons why Mars may continue to remain “20 years from now.”

Read at your leisure!



Barker, D. C., 2015, **The Mars imperative: Species survival and inspiring a globalized culture.** Acta Astronautica, 107, 50-69, doi.10.1016/j.actaastro.2014.11.006.



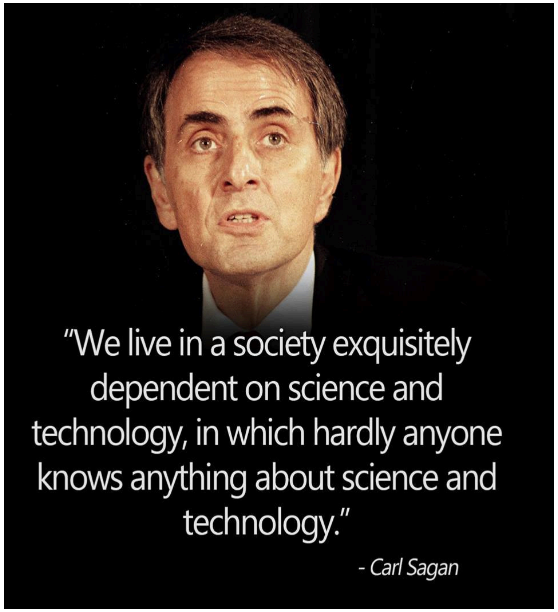
Backup

A needed paradigm shift

The "why" and "when" of sending humans to Mars should be addressed from the beginning.

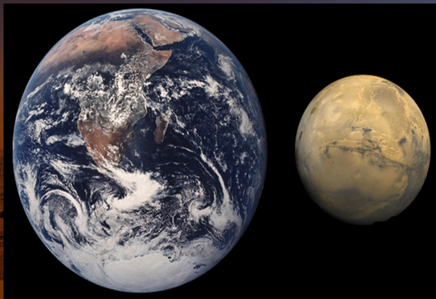
A full discussion should include constraints and competition to future funding and programs as a result of projected population and social trends, pollution, climate change, human conflict, governmental partisanship/waste, reduced public attention span/support, military and social expenditures, ect.

A crucial implication being that our focus should be directed towards **permanent** and **sustainable** human **settlement** of Mars through the identification and acquisition of *water reserves,* as this endeavor will likely not happen by scientific objectives alone.



For example, the directions given in this workshop and NASAs historical "modus operandi" continue to highlight the priorities and goals of a fixated science, engineering and bureaucratically burdened community without regard to a permanent and sustainable context by addressing "Why" we should go to Mars.

Vocabulary places science over resources: "ROIs are areas that are relevant for scientific investigation and/or development/maturation of capabilities and resources necessary for a sustainable presence."

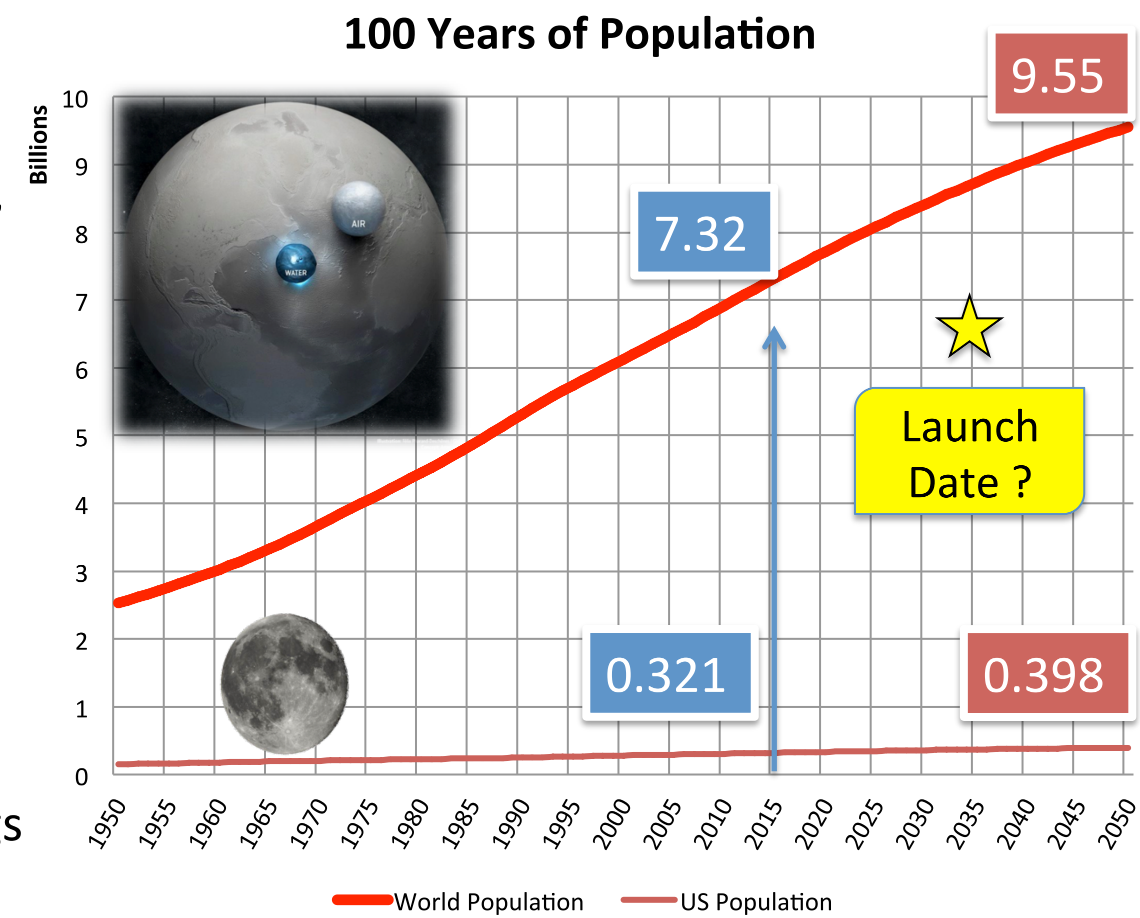


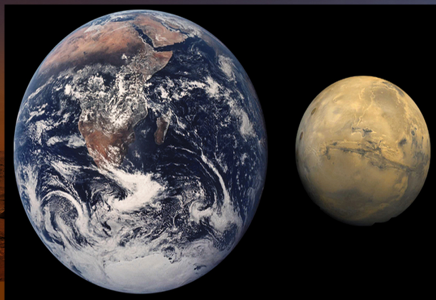
Backup

A needed paradigm shift

Given present population trends and the associated trends in resource depletion, environmental degradation, human conflict, migration and economic impacts, the *likelihood* of future budgets deviating from the trends or levels of the past 50 years is increasingly difficult if not improbable.

- No one should assume things will change in favor of Humans to Mars.

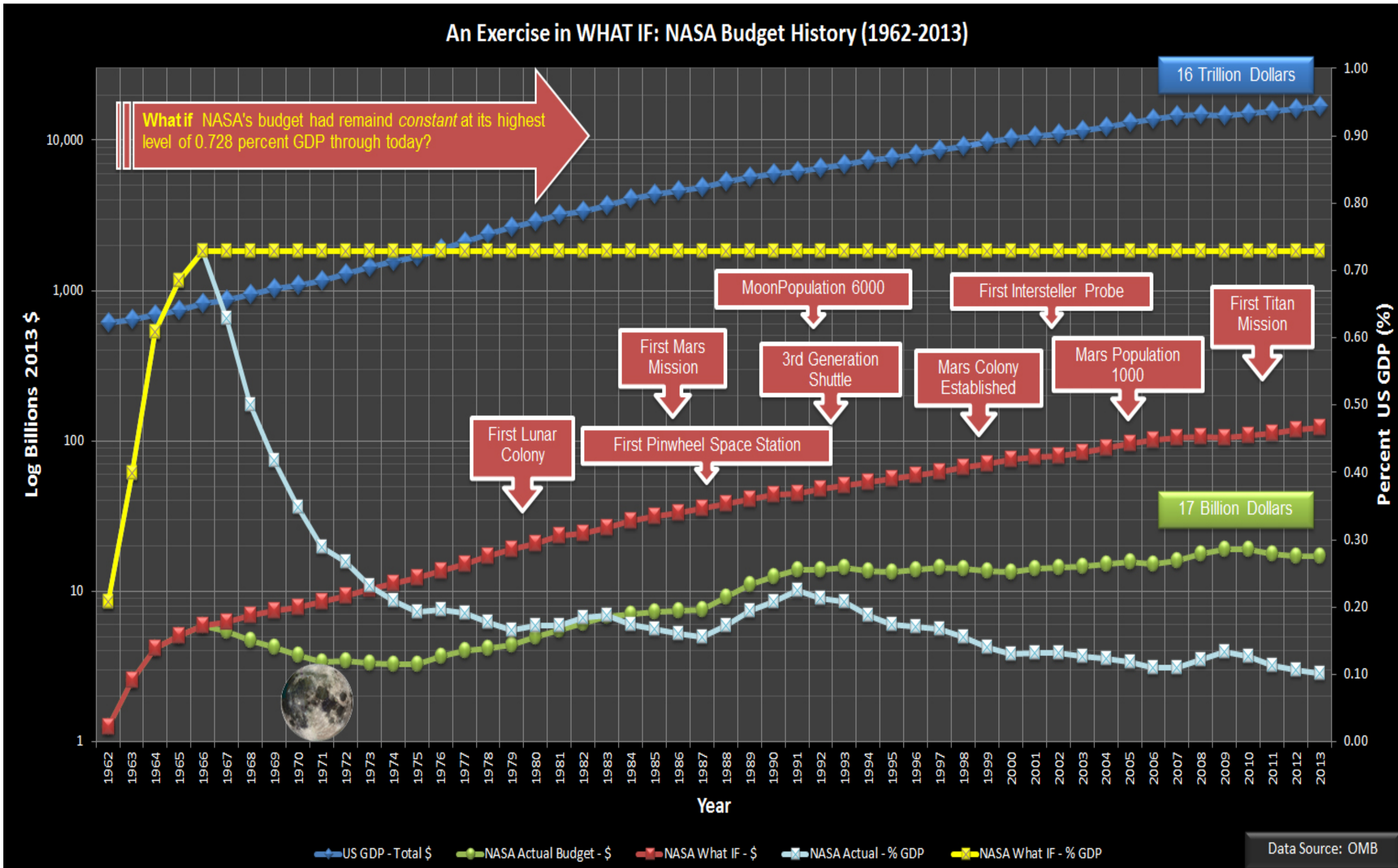




A window of opportunity drawing to a close?

Backup

What If $$$$



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